Probabilistic Prediction of Riverine Bathymetry

K. Todd Holland
Seafloor Sciences Branch, Naval Research Laboratory, Stennis Space Center, MS 39529
Phone: (228) 688-5320 Fax: (228) 688-4657 Email: tholland@nrlssc.navy.mil

Award Number: (N0001411WX20740)

LONG-TERM GOALS

The goal of this effort is to develop methods for imaging riverine flows that can be applied under operational Naval scenarios to aide in the prediction of relevant riverine conditions (e.g. hydraulic depth, thalweg position, etc.) and that are consistent with related efforts to develop analytic and probabilistic forecasting models for the riverine environment.

OBJECTIVES

The objectives of this effort are to develop advanced methods of analysing motion imagery to estimate riverine flows in conjunction with the assessment of existing and newly developed riverine modeling frameworks. These frameworks include a probabilistic system being developed to predict the value and uncertainty of variables that are relevant to riverine operations, such as water depth. As such models are proceeding as related efforts outside the scope of this award, the focus of this work is to assure that the coverages, resolutions, accuracies and overall quality of estimated flow speeds and directions are consistent with use in these frameworks and applicable to operational scenarios. In addition, we seek to compare this optical approach to additional methods of estimating flows such as with GPS-equipped surface drifters or Unmanned Underwater Vehicles (UUV).

APPROACH

The focus of the probabilistic design is to rigorously incorporate uncertainty in natural river conditions relating to river width, surface flow speeds, discharge ranges, and/or river path into an operational decision aide for estimating river depths. An example of this sort of decision is the probabilistic certainty that a particular river location can be waded across or is too shallow to navigate using a boat of a certain size. The key to this approach over the long list of similarly motivated projects that use hydraulic geometry as a statistical framework (see Smith and Pavelsky, 1998 as an example) is our recent ability to obtain river currents using remote sensing.

The technical approach for this remote sensing task is founded on capability developed for littoral applications using Particle Image Velocimetry (PIV) to monitor surf zone currents. We have extended these algorithms to process optical imagery of riverine flows. Experiments on the Wolf River, MS and the Kootenai River, ID were conducted to assess the surface signatures of these type flows using both standard Red-Green-Blue (RGB) and near Infrared (IR) cameras. These experiments had additional observations of surface flows from in-situ and Lagrangian instrumentation including GPS-equipped

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **30 SEP 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**
4. TITLE AND SUBTITLE **Probabilistic Prediction of Riverine Bathymetry**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Seafloor Sciences Branch,Stennis Space Center,MS,39529**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

drifters. These observations were assessed within 3 modeling frameworks: the Bayesian Riverine Expert System being developed in coordination with N. Plant (USGS), Deltares' SOBEK 1D/2D models, and USGS riverine models such as FaSTMECH.

WORK COMPLETED

We have shown good success using synthetic data of several types. Primarily, a classification network has been constructed to enable the natural segmentation of source data into optimal categories to be used as specific training sets. We have also shown significant skill (r^2 value of 0.9) at reproducing simulations of the Kootenai river meander section using the SOBEK model 1-D simulations as probabilistic training. For example, we have shown (Figure 1) that for this river segment the discharge equation can be effectively parameterized within the Bayesian framework using only width and velocity such that expected depth is nearly as skillful as with 3 parameters. For example, using a specific width and velocity setting yields a expected depth of 6.38 +/- 1.5 m whereas using discharge, width, and velocity gives the depth as 5.85 +/- 0.49 m. Both expectations are operationally equivalent.

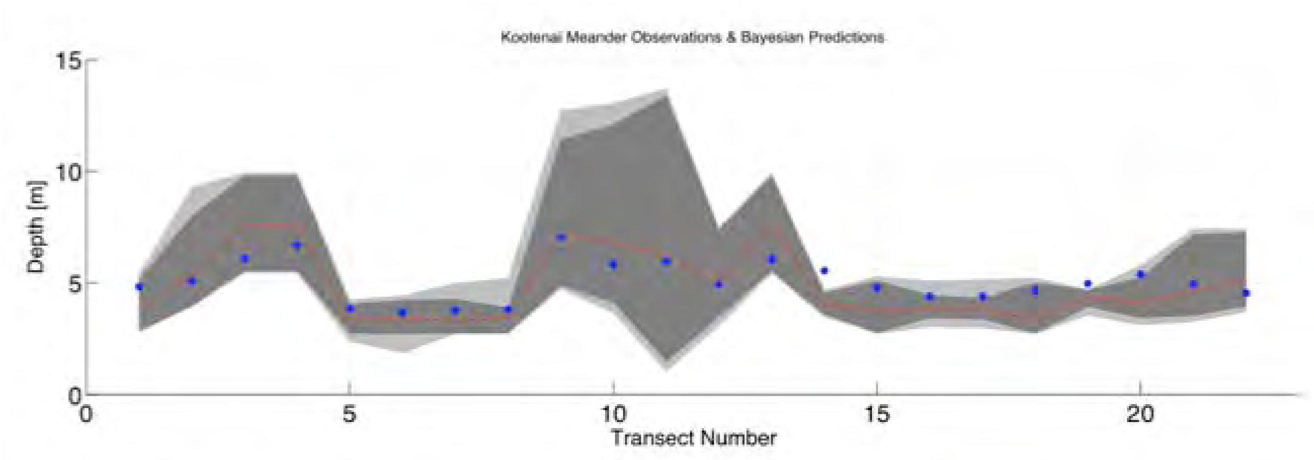

Figure 1. Example of probabilistic skill with respect to application of new observed forcing to synthetically trained network (of same river). Depth observations – blue, most probable depth – red, 90/95% confidence interval – dark/light gray.

More skill has resulted from the use of field data consisting of 96,154 observations at 1687 USGS gaging locations. Initial results with hindcast estimates suggest that skill in terms of confident and correct answers exceeds 90%. Common test sets for Idaho, FL and MS rivers have been developed to require conformity in independent test case testing through selection of final input and output file formats. The design of the probabilistic network (in terms of number and widths of statistical bins) is being optimized based on this training set.

Other completed tasks:

NRL organized a workshop on 27-28 October 2010 to discuss the relationship of academic efforts supported by ONR to the development and testing of the probabilistic prediction system framework. 15 scientists were in attendance for the discussion and significant collaboration opportunity was identified in terms of upcoming experiments, ground-truth data sources, modeling advances, and especially USGS training data.

An additional data collection of currents, water levels and bathymetry was obtained on 30 March 2011 at the Apalachicola Regional Training Center in support of field assessments to be completed by Navy operators.

In addition, UAS imagery was evaluated on the Salt River from flights at Fort Knox, KY over 11-12 May. The observations showed visible contrast in the shortwave IR band that would be suitable for surface current estimation, although related research has indicated that midwave IR is preferable. Unfortunately, due to the flooding of the nearby Ohio River, current speeds were small, so evaluation of PIV current estimation algorithms was limited. This flight represents a significant accomplishment in terms of assessment of the UAS derived currents.

RESULTS

Detailed testing using 249 independent world-wide measurements by Moody and Troutman (2002) has shown for river cases with observed depths < 1m (representing a possible fording location or a hazard to boat navigation), 88% were identified corrected using this probabilistic network design. Largest deviations were also most uncertain. These “Moody” test-case rivers had widths ranging from <10 to 3130 m and discharges (in cms) spanning 6 orders of magnitude. Hindcast analysis of the probabilistic network indicates exceptional reliability (forecasting the observed probability) compared to other network designs and background climatology. Sharpness (‘knowing that you know’) was very high.

We have recently planned a substantial data field collection effort on the Hanford Reach of the Columbia River near Richland, WA, which represents an ideal testing environment with a wide range of depths and river widths. Velocity observations from remote sensing will be obtained from 5-8 October 2011 (in addition to deployment of riverine drifters and small AUVs) and related operational techniques for determining widths, slopes and discharges will be exercised. Ground truth measurements of these same parameters will be sampled along the 28 cross-river transects. The experiment location is shown in Figure 2.

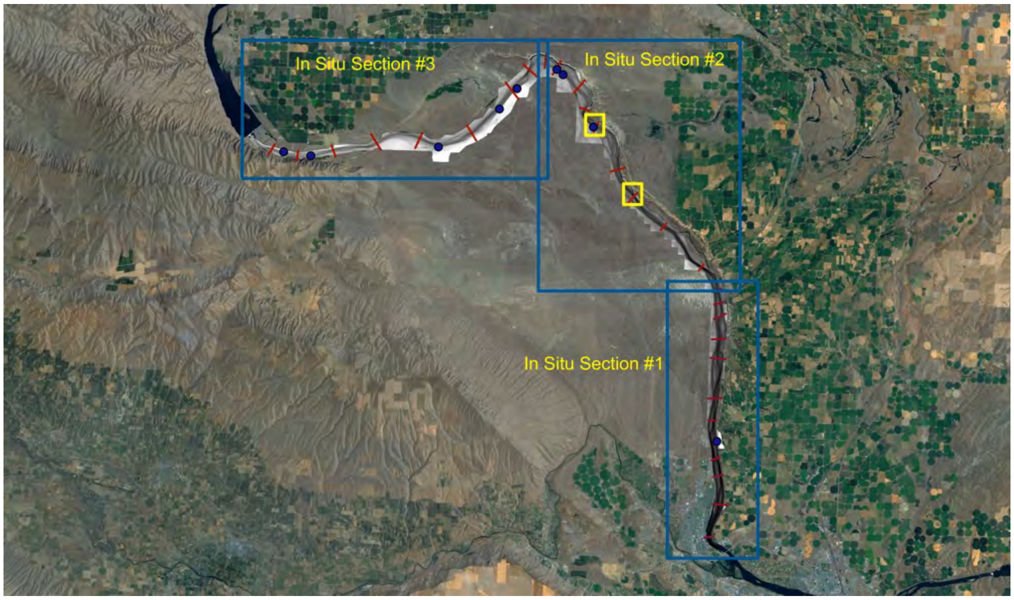

Figure 2. 82-km Hanford Reach of the Columbia River (WA)

IMPACT/APPLICATIONS

The developed methods are directly applicable to video obtained from Unmanned Aircraft Systems and perhaps to video from riverine surface craft used by Naval forces. Ongoing research efforts are aimed at taking these observations of surface flows and ingesting them into inversion procedures to estimate riverine characteristics such as river depth using either stasistical (this effort) or deterministic methods.

RELATED PROJECTS

DARPA's RiverEye effort

REFERENCES

Moody, J.A., and Troutman, B.M, 2002, Characterization of the spatial variability of channel morphology: Earth Surface Processes and Landforms, v. 27, no. 12, p. 1251-1266.

Smith, L. C., and T. M. Pavelsky (2008), Estimation of river discharge, propagation speed, and hydraulic geometry from space: Lena River, Siberia, Water Resour. Res., 44, W03427, doi:10.1029/2007WR006133.